NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

# MSC INTERNAL NOTE NO. 69-FM-81

April 11, 1969



# LUNAR LANDMARK TRACKING ATTITUDE STUDIES

(NASA-TM-X-69720) LUNAR LANDMARK TRACKING ATTITUDE STUDIES (NASA) 39 p

N74-70857

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LUNAR MISSION ANALYSIS BRANCH
MISSION PLANNING AND ANALYSIS DIVISION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

MSC INTERNAL NOTE NO. 69-FM-81

# PROJECT APOLLO

# LUNAR LANDMARK TRACKING ATTITUDE STUDIES

By C. R. Hunt
Mission Design Section
TRW Systems Group

April 11, 1969

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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# LUNAR LANDMARK TRACKING ATTITUDE STUDIES

By C. R. Hunt
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## 1. SUMMARY AND INTRODUCTION

### 1.1 General

This document presents the results of a study of possible vehicle attitude modes for lunar landmark tracking. This study was carried out with the intention of using the results in developing the lunar orbit attitude profiles for mission F and subsequent lunar orbit missions. The primary concern is the amount of time available for acquisition and tracking of the lunar landmark. As a result, tracking time and total acquisition to termination time were investigated as a function of vehicle attitudes and vehicle attitude rates.

Current optical constraints and crew preferences were taken into account in the selection of the modes to be studied. In general, the modes considered involved inertial holds or orbital rates with pitch rates or roll rates added as the spacecraft approaches the landmark to keep the landmark in the optics fields of coverage for a longer time. The optical fields of coverage are reduced by LM blockage when the CSM and LM are docked; therefore, attitude modes were considered for both the docked and undocked spacecraft configuration. Although other modes were studied, only those modes that seem practical and satisfy the minimum tracking time and optical constraints are presented in this document.

### 1.2 Data Generation

The geometry and attitude data were generated using the Apollo Reference Mission Program, Version ARM06. A portion of the May 17 F mission trajectory was used, with the spacecraft in an approximately 60-nautical mile circular lunar parking orbit. The landmark used was a fictitious lunar landmark picked to lie on the spacecraft orbital ground track. Although most lunar landmarks will not lie exactly on the ground track, they are selected to lie near the spacecraft ground track. The landmark tracking geometry remains approximately the same for landmarks close to the ground track.

## 2. SYMBOLS

| | |
|---|---|
| ARM06 | Apollo Reference Mission Program, Version ARM06 |
| CPA | closest point of approach |
| CSM | command and service module |
| HGA | high-gain antenna |
| IMU | inertial measurement unit |
| LM | lunar module |
| LOS | line of sight |
| MSFN | Manned Space Flight Network |
| RCS | reaction control system |
| REFSMMAT | reference to stable member coordinate transformation matrix |
| SCT | scanning telescope |
| SXT | sextant |

# 3. CONSTRAINTS

## 3.1 Optical Fields of Coverage

The CSM optical instruments which may be used for landmark tracking are the sextant (SXT) and the scanning telescope (SCT). The SXT is a 28-power optical instrument with dual lines of sight, each line of sight (LOS) having a 1.8-degree true field of view. One LOS is fixed along the SXT shaft axis, which in turn is fixed relative to the navigation base. The second LOS may be varied by rotations about the SXT shaft and trunnion axes. The variable LOS is used when landmark tracking with the SXT. The SCT is a one-power optical instrument with a 60-degree true field of view. The SCT LOS may be varied by rotations about the SCT shaft and trunnion axes. The SXT and SCT shaft axes are parallel to an axis that lies in the CSM X-Z plane approximately 57.5 degrees from the CSM X-axis toward the Z-axis. The trunnion axes are perpendicular to the shaft axes. The optics shaft and trunnion angles are the angles of rotation about the shaft and trunnion axes required to place the center of the SXT or SCT field of view along the LOS to the landmark. The trunnion angle is the angle between the shaft axis and the landmark LOS. The shaft angle is the required angle of rotation about the shaft axis, measured positively counterclockwise about the shaft axis. A 0-degree shaft angle implies the landmark LOS lies in the CSM X-Z plane and between the CSM X-axis and the shaft axis. Further information on the CSM optics may be obtained from Reference 1.

By means of the trunnion and shaft axis rotations, the SXT can scan a hemisphere about the SXT shaft axis. However, due to physical obstructions and LM blockage, the effective SXT field of coverage is reduced to that shown in Figure 1. Likewise, the effective SCT field of coverage is shown in Figure 1. These effective fields of coverage were taken from Reference 2. The shaded area in the SCT field of coverage (other than LM blockage) represents diminishing brightness of the target from the inside of the cone to the outer edge of physical obstruction. The SXT also has an area of diminishing brightness of about the same magnitude which is not shown in Figure 1. These areas of diminished brightness may be used in tracking bright targets. The approximate limits of the SXT field of coverage in terms of SXT shaft and trunnion angles are given in Figure 2, while the SCT field of coverage limits in terms of SCT shaft and trunnion angles are given in Figure 3. These figures were obtained by scaling Figure 1, and, therefore, should be considered only as approximate limits.

For the purpose of this document, it will be assumed that the SCT will be used to acquire the landmark, and the SXT will be used to track the landmark. The optical field of coverage will be assumed to be limited by the outer edges of physical blockage, and the area of diminishing brightness will be utilized.

### 3.2 Optical Blind Zone

As a result of the maximum rate limits of the optics shaft and trunnion angles, there are certain zones in the coverage area where the optics LOS cannot keep up with the motion of the landmark. This occurs when the ground track of the optics shaft axis passes close to the landmark. In current mission planning the optical blind zone is avoided by maneuvering the spacecraft such that the minimum trunnion angle is at least 10 degrees.

### 3.3 Tracking Constraints

Current mission requirements (Reference 3) are that five marks will be made on the landmark during the tracking period with the first mark being taken when the spacecraft is between 30 and 40 degrees above the local horizon. The marks should be made at approximately equal time increments with a minimum increment between marks on the order of 25 seconds. This places a lower limit on the time required for landmark tracking of 100 seconds between the first and last marks. Time required for acquisition of the landmark would be in addition to the minimum 100 seconds.

There is an upper limit on spacecraft attitude rates which may be used to extend the tracking time. CSM attitude rates greater than or equal to 2/3 degree per second will result in rejection of the sighting marks by the command module computer.

### 3.4 Additional Attitude Constraints

In addition to the optical systems constraints, there are several general attitude constraints which must be observed in determining vehicle attitude modes for landmark tracking. IMU gimbal lock should be avoided; RCS propellant should be conserved; and CSM S-band HGA communications with MSFN should be provided whenever possible.

IMU gimbal lock is approached when the IMU outer gimbal axis approaches the inner gimbal axis. In current mission planning, the IMU REFSMMAT used during landmark tracking will represent an essentially in-plane IMU alignment. Using this assumption, IMU gimbal lock will not be approached if the CSM X-axis is maintained within 45 degrees of the lunar orbit plane.

To avoid excessive use of RCS propellant, frequent attitude maneuvers must be avoided. This becomes an important constraint when several landmarks must be tracked on each vehicle revolution. In this case, an attitude mode that would not require large attitude reorientations between landmark sightings should be used.

A vehicle attitude that allows S-band HGA communications with MSFN should be provided whenever possible. The CSM HGA and the CSM optics have fields of coverage that lie mostly on the same side of the spacecraft. Since the CSM optics must be pointed at the moon during landmark tracking, CSM HGA communications with MSFN will not be available except for rare cases of landmark-spacecraft-earth geometry.

## 4. GEOMETRY

The landmark geometry for an approximate 60-nautical mile circular lunar orbit is shown in Figure 4. The topocentric horizon is defined by a plane containing the landmark and normal to the landmark radius vector. The elevation angle of the spacecraft is taken as the angle between the topocentric horizon plane and the landmark to vehicle LOS. The spacecraft crosses the topocentric horizon approximately 390 seconds before the closest point of approach (CPA) to the landmark. The acceptable marking region for landmark tracking will be taken as the region in which the LOS to the landmark makes an angle of no greater than 55 degrees with the vertical to the landmark. This region extends approximately 90 seconds on either side of the CPA. Marks taken inside this region should satisfy the tracking constraints listed in Section 3.3.

Three geometry plots are included to further define the landmark tracking geometry. Figure 5 presents an elevation angle versus time plot, while Figures 6 and 7 present an elevation rate versus elevation angle plot, and a slant range versus time plot, respectively. These plots demonstrate that the elevation angle changes very slowly at low elevation angles but increases rapidly as the spacecraft approaches the CPA. Figure 6 also shows that, in general, if the spacecraft is given a uniform attitude rate from topocentric horizon to topocentric horizon, there will be a period of time during which the spacecraft attitude will be changing at a rate faster than the landmark LOS will be moving, followed by a period in which the landmark LOS is changing faster than the spacecraft attitude, and then another period with the spacecraft attitude changing faster than the landmark LOS. In terms of the spacecraft optical systems, this would mean two changes in the direction of motion of the landmark. These direction changes may be easily avoided by starting and ending the attitude rates at relatively high elevation angles and using low attitude rates. For example, if a uniform attitude rate is maintained within the acceptable marking region (35 degrees elevation to 35 degrees elevation), the upper limit of the rate which may be used without changes in the direction of motion of the landmark is 0.34 degree per second.

# 5. LANDMARK TRACKING MODES

## 5.1 Mode I

Mode I landmark tracking consists of an inertial attitude hold with the CSM X-Z plane approximately in the orbit plane. As the spacecraft approaches the landmark, a pitch rate is added to allow the landmark to remain in the optical fields of coverage while the CSM is in the acceptable marking region. This mode of landmark tracking is most practical for CSM/LM docked landmark sightings where LM blockage obscures part of the optical fields of coverage, and where only one landmark is tracked per vehicle revolution. The following discussion assumes the docked CSM/LM vehicle configuration. The amount of tracking time available for this mode is a function of the initial inertial attitude, the amount of pitch rate added, and the time when the pitch rate is started. Two different pitch rates are presented, 0.2 degree per second and 0.3 degree per second. A slightly different initial inertial attitude is used with each rate, but each rate is started at the same time. The pitch rate is added at 35 degrees elevation (90 seconds before the CPA). This allows the landmark to be visually identified before the pitch rate is started, but allows the rate to be added before marking begins.

The geometry of mode I type landmark tracking with a -0.3 degree per second pitch rate added at 35 degrees elevation is shown in Figure 8. The initial inertial attitude is such that the CSM is pitched 2.1 degrees below the local horizontal orientation at 90 seconds before the CPA. The -0.3 degree per second pitch rate is maintained until the vehicle exits the acceptable marking region approximately 90 seconds after the CPA. At the termination of the pitch rate the CSM X-axis lies approximately 47 degrees below the local horizontal orientation. The landmark enters the SCT field of coverage 148 seconds before the CPA (21 degrees elevation) and enters the SXT field of coverage 112 seconds before the CPA (28.2 degrees elevation). The landmark is still in both the SXT and SCT fields of coverage at the termination of the pitch rate. The landmark is in the SXT field of coverage for the entire 180 seconds the spacecraft is in the acceptable marking region. The landmark enters the SCT field of coverage 58 seconds before and the SXT field of coverage 22 seconds before the start of the pitch rate. This allows time for the acquisition of the landmark before the pitch rate is added. The -0.3 degree per second pitch rate is slightly higher than the minimum rate needed. This means that if a small delay is encountered in setting up the attitude rate or if a slightly less than 0.3 degree per second pitch rate is established, the landmark will still remain in the SXT field of coverage until the spacecraft exits the acceptable marking region.

A slightly different mode I tracking sequence uses the addition of a -0.2 degree per second pitch rate at 35 degrees elevation. The initial inertial attitude is such that the CSM is pitched 8 degrees below the local horizontal orientation at 90 seconds before the CPA. The -0.2 degree per second pitch rate is continued until the vehicle exits the acceptable marking region 90 seconds after the CPA. At the termination of the pitch rate, the CSM X-axis lies 34.9 degrees below the local horizontal orientation. The landmark enters the SCT field of coverage 118 seconds before the CPA (26.9 degrees elevation) and enters the SXT field of coverage 92 seconds before the CPA (34.1 degrees elevation). The landmark just exits the SXT field of coverage at the termination of the pitch rate. The landmark is in the SXT field of coverage for the 180 seconds the spacecraft is in the acceptable mark region and enters the SCT field of coverage 28 seconds before and the SXT field of coverage 2 seconds before the start of the pitch rate. The time constraints are much tighter than when using the -0.3 degrees per second rate, and this probably offsets the advantages of using a smaller pitch rate.

In Figure 8 and in the tracking times given above, the vehicle maneuver to avoid the optics blind zone constraint is not added. When using a pitch mode type sighting, this constraint may be satisfied with a small roll maneuver. The magnitude and direction of the roll maneuver depends on how far the landmark is from the spacecraft orbital ground track, and to which side. An in-plane landmark requires the maximum roll, while a landmark far enough from the orbital ground track that the minimum angle between the optical shaft axis and the landmark line of sight is 10 degrees or more requires no maneuver at all. The vehicle roll may be added either before or after the pitch rate is begun. If the maneuver is added after the pitch rate is set up, the CSM X-axis remains in the orbital plane. If the maneuver is added before the pitch rate is started, the CSM X-axis pitches out of plane, but since the required roll is small, no appreciable tracking time is lost.

A plot of landmark LOS, in SXT shaft and trunnion angles, is presented in Figure 9. A Mode I tracking profile with a -0.3 degree per second pitch rate was used. A roll maneuver has been added before the start of the pitch rate to obtain a minimum trunnion angle of 10 degrees. The roll is added to the initial inertial hold so the inertial attitude is such that the CSM is pitched a -2.1 degrees and rolled 10.0 degrees from the local horizontal orientation at 90 seconds before the CPA. The local horizontal angles at the completion of the pitch rate are a pitch of -46.6 degrees, yaw of -8.1 degrees, and a roll of 5.9 degrees. In this example, by rolling away from the LM blockage, additional SXT acquisition time is obtained.

### 5.2 Mode II

Mode II landmark tracking consists of a local attitude hold with a pitch rate added as the spacecraft approaches the landmark to allow the landmark to remain in the optical fields of coverage for a longer time. This mode is most suited for CSM/LM docked landmark sightings, and the following discussion assumes the docked CSM/LM vehicle configuration. The local horizontal attitude is such that the CSM is pitched 5 degrees above the local horizontal orientation. This attitude allows the landmark to be in the SCT field of coverage as the spacecraft crosses the topocentric horizon. The landmark enters the SXT field of coverage 174 seconds before the CPA (16. 9 degrees elevation). If a pitch rate of -0. 3 degrees per second is started at 90 seconds before the CPA, the landmark remains in the SXT field of coverage until the termination of the pitch rate at 90 seconds past the CPA. The spacecraft X-axis lies 39. 9 degrees below the local horizontal orientation at the termination of the pitch rate. This mode provides the maximum amount of acquisition and tracking time available but requires two attitude rates. The optical blind zone constraint may be satisfied as in mode I landmark tracking by rolling the spacecraft to assure a minimum trunnion angle of at least 10 degrees.

## 5. 3 Mode III

Mode III landmark tracking involves maintaining a local attitude hold throughout the landmark tracking period. This mode is best suited for CSM undocked landmark sightings where LM blockage is not a problem and where several landmarks are tracked in each vehicle revolution. This mode does not require large vehicle reorientations between landmark tracking periods and, therefore, saves on RCS propellant. The optimum local horizontal attitude is a pitch of 22 degrees below the local horizontal orientation. The geometry of a mode III type tracking sequence during a CSM undocked sighting is shown in Figure 10. For CSM undocked sightings, the landmark enters the SXT field of coverage 125 seconds before the CPA (25. 7 degrees elevation) and enters the SCT field of coverage 100 seconds before the CPA (32. 0 degrees elevation). The landmark exits the SXT field of coverage 56 seconds past the CPA (49. 7 degrees elevation). Although the tracking and acquisition times are significantly reduced, the landmark remains in the SXT field of coverage for 146 seconds within the acceptable mark region, with at least 50 seconds of marking time on either side of the CPA.

Assuming the same mode III type landmark tracking is used on CSM/LM docked sightings, LM blockage further reduces the acquisition and marking time. The landmark enters the SCT field of coverage 71 seconds before the CPA (41. 9 degrees elevation) and enters the SXT field of coverage 54 seconds before the CPA (50 degrees elevation). The landmark exits the SXT field of coverage 56 seconds past the CPA (49. 7 degrees elevation). The landmark remains in the SXT field of coverage for 110 seconds within the acceptable mark region, but acquisition time is appreciably reduced. The optical blind zone constraint may be satisfied in mode III landmark tracking by rolling the spacecraft as the landmark is approached to assure a minimum trunnion angle of at least 10 degrees.

### 5.4 Mode IV

Mode IV landmark tracking differs from the other three modes discussed in that it is a roll mode rather than a pitch mode. The mode consists of an inertial attitude hold with the addition of a roll rate as the landmark is approached to allow the landmark to remain in the optical fields of coverage for a longer period of time. The roll mode allows the landmark to be tracked without interference from LM blockage and, therefore, is best suited to CSM/LM docked landmark sightings. The CSM X-axis must be out of the orbital plane for roll mode landmark sightings, and thus, IMU gimbal lock must be avoided during the sighting sequence. Gimbal lock may be avoided by assuring that the CSM X-axis is no more than 45 degrees out of the orbital plane. For optimum optical coverage, the initial inertial hold and roll rate should be such that the CSM X- and Z-axes straddle the landmark at the CPA. That is, the CSM X- and Z-axes are on opposite sides of the orbital plane, and the CSM X-Z plane is coincident with the plane containing the landmark and the orbital angular momentum vector. Taking into account the attitude constraints defined above, a general SXT shaft and trunnion angle plot of a mode IV landmark sighting using a continuous -0.3 degree per second roll rate was developed. This plot is presented in Figure 11. This plot may then be used in selecting the time to start the roll rate. If a -0.3 degree per second roll rate is started at 90 seconds before the CPA (35 degrees elevation), the resulting SXT shaft and trunnion plot is as given in Figure 12. The initial inertial attitude is such that the local horizontal angles at the start of the roll rate are a pitch of -94.6 degrees, yaw of 45.0 degrees, and a roll of 117.0 degrees. The -0.3 degree per second roll rate is maintained while the CSM remains in the acceptable marking region and is terminated 90 seconds past the CPA (35 degrees elevation). The CSM local horizontal angles at the termination of the roll rate are a pitch of -85.4 degrees, yaw of 45.0 degrees, and a roll of 63.0 degrees. The landmark enters the SCT field of coverage 205 seconds before the CPA (13.3 degrees elevation) and enters the SXT field of coverage 170 seconds before the CPA (17.7 degrees elevation). The landmark is well within the optical fields of coverage at the termination of the roll rate.

Since the CSM X-axis is only 45 degrees out of the lunar orbital plane, the minimum trunnion angle for an in-plane landmark is approximately 12 degrees. This satisfies the optical blind zone constraint. For landmarks off the orbital ground track, the minimum trunnion angle can be kept greater than 10 degrees by pitching the CSM slightly more or less out of plane.

There is a slight variation of the pure roll mode which may also be used for landmark tracking. This is a combination yaw-roll mode. The CSM X-axis is also maneuvered to help keep the landmark in the optical fields of coverage. This mode is similiar to the roll mode considered above and will not be further discussed.

## 6. CONCLUSIONS

Each of the landmark tracking modes presented satisfies the minimum tracking time, optical, and general attitude constraints for landmark tracking. The tracking times and acquisition times for each mode may be altered by using different initial attitudes, attitude rates, or rate start times. The specific values used in this document reflect an attempt to make each mode practical and to center the available tracking time near the landmark zenith. Modes I, II, and III have been presented with initial attitudes such that the CSM X-axis is generally forward of the spacecraft local vertical and the CSM Z-axis generally behind the local vertical. Entirely analogous attitudes exist which have the CSM Z-axis generally forward of the spacecraft local vertical and the CSM X-axis to the rear. These "backward" attitudes would provide the same acquisition and tracking time as the "forward" positions but would provide better communication in some cases.

Mode I landmark tracking is best suited for CSM/LM docked landmark sightings. Adequate acquisition and tracking time is provided, even with LM blockage, by using the 0.3-degree per second pitch rate. The mode is relatively easy to use in that the required inertial attitude may be established long before the tracking period, and the required pitch rate may be easily added from the inertial attitude hold. Attitude reorientations are required between landmarks when sighting on a series of landmarks. This might require excessive RCS propellant, but present mission planning is that only one landmark will be tracked per vehicle revolution during docked landmark sightings. Mode I also requires that the location of the landmark, with respect to the spacecraft ground track, be well known in order that the initial inertial attitude may be determined. This is also satisfied during docked landmark sightings, because the landmark positions for docked landmark sightings are fairly well known.

Mode II landmark tracking has many of the same advantages and disadvantages as mode I landmark tracking. It too is best suited to CSM/LM docked landmark sightings. Mode II tracking provides the maximum available acquisition and tracking time. One disadvantage is that it is a multiple rate mode, involving starting a 0.3-degree per second pitch rate from an orbital rate. Attitude reorientations are required between landmarks when sighting on a series of landmarks, but if the mode is used for single landmark docked sightings, this is not a problem. This mode is more flexible than mode I in that the vehicle has a constant attitude with respect to the local horizontal during acquisition. This allows an easy survey of the ground track ahead of the landmark and more advantageous acquisition of initial points. Since the initial local attitude of the vehicle is the same for all landmarks, the location of the landmark does not have to be as well known, and different landmarks may be used in real time by initiating the pitch rate with respect to the new landmark with no attitude change.

Mode III landmark tracking is the mode best suited to CSM undocked landmark sightings. The acquisition and tracking time available is less than the other three modes, but with no LM blockage the time available should be adequate. No large attitude maneuvers are required between landmarks when sighting on a series of landmarks, and the location of the landmark does not have to be as well known as for mode I landmark tracking. Since current mission planning calls for several widely dispersed landmarks to be tracked on each vehicle revolution during undocked sightings, mode III requires less RCS propellant. This mode provides better survey of the ground track than the other modes during undocked landmark tracking.

Mode IV landmark tracking is very similar to mode I landmark tracking except that a roll rate rather than a pitch rate is used. The advantages and disadvantages of this mode are very similar to those for mode I landmark tracking and arise from the requirement for an inertial attitude hold. This mode is best suited for CSM/LM docked landmark sightings. Adequate acquisition and tracking time is provided, and LM blockage is totally avoided. The main advantage of mode IV landmark tracking over mode I landmark tracking is that the roll rate is cheaper to establish than the pitch rate, thus reducing RCS propellant requirements. One disadvantage would be having to maneuver the CSM X-axis out of the orbit plane before initiation of the sightings and then back into the orbit plane upon completion of the sightings.

In developing the mission F lunar orbit attitude profile (Reference 4), mode I landmark tracking has been used for CSM/LM docked landmark sightings, and mode III landmark tracking has been used for CSM undocked landmark sightings. Mode I landmark tracking fits easily into the mission F flight plan and provides adequate tracking time and acquisition time for the two docked landmark sightings. Mode III landmark tracking is used to conserve RCS propellant during the undocked landmark sightings, for which three or four landmarks are tracked on each orbit for four consecutive orbits.

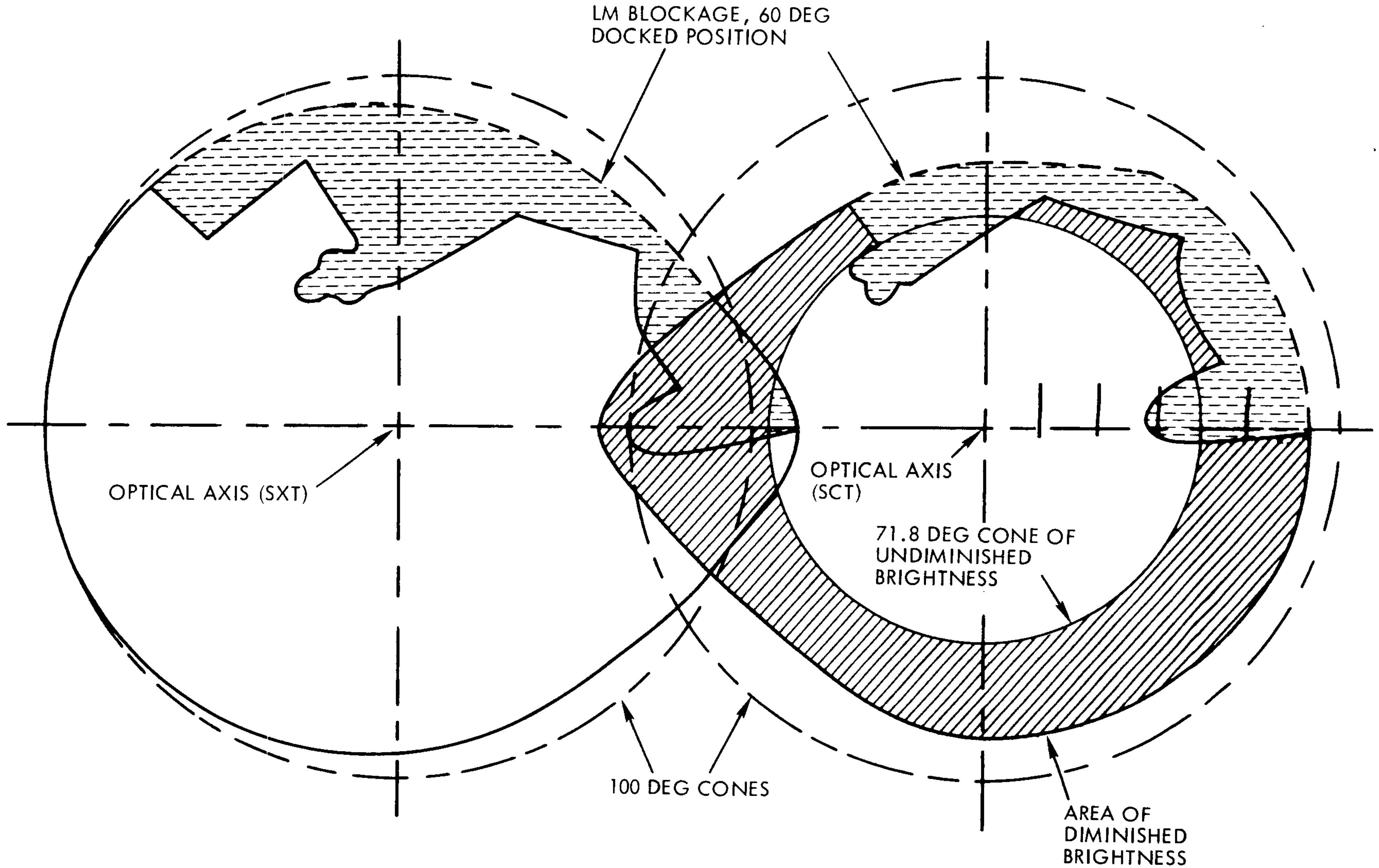


Figure 1. SXT and SCT Fields of Coverage

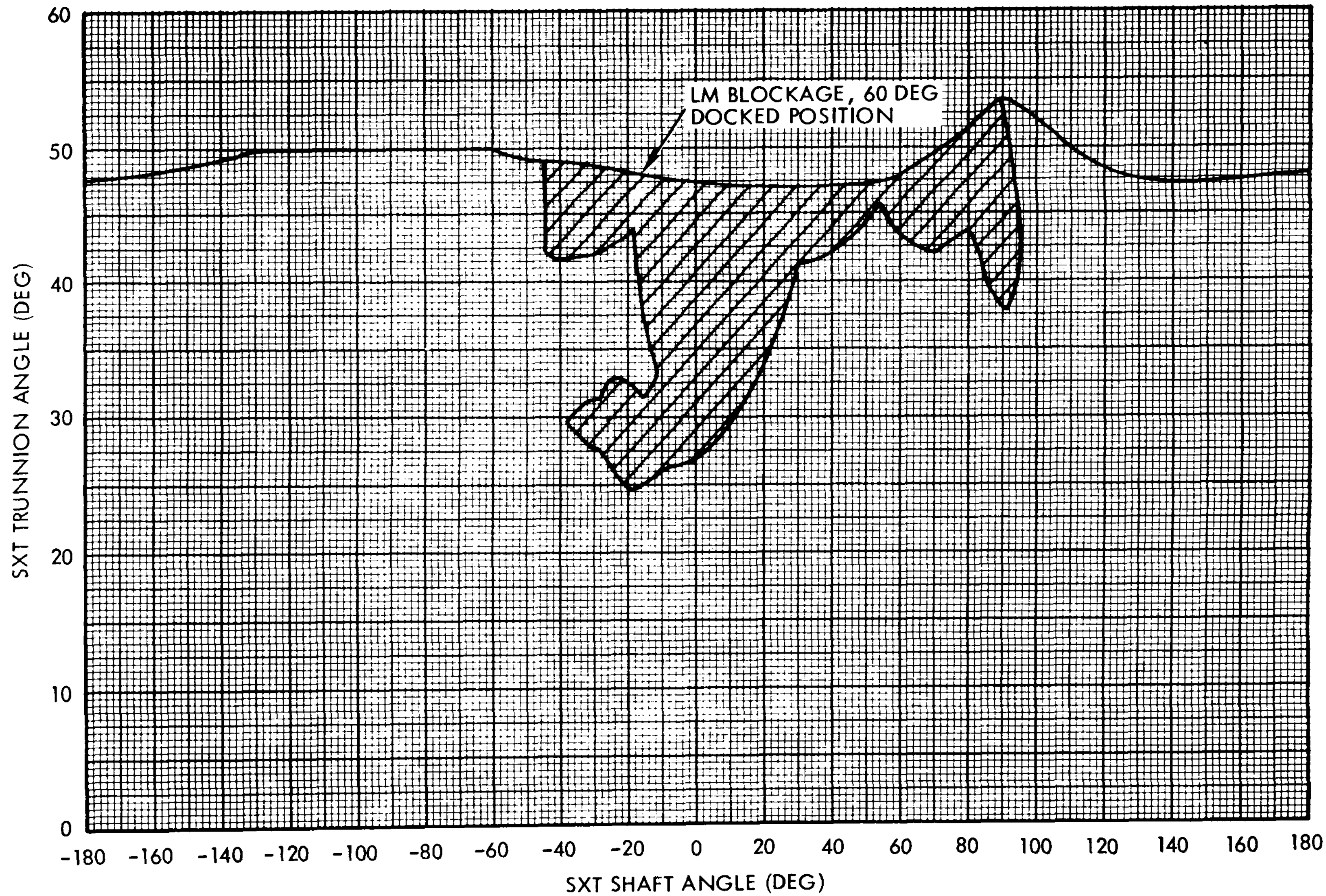


Figure 2. SXT Shaft and Trunnion Limits

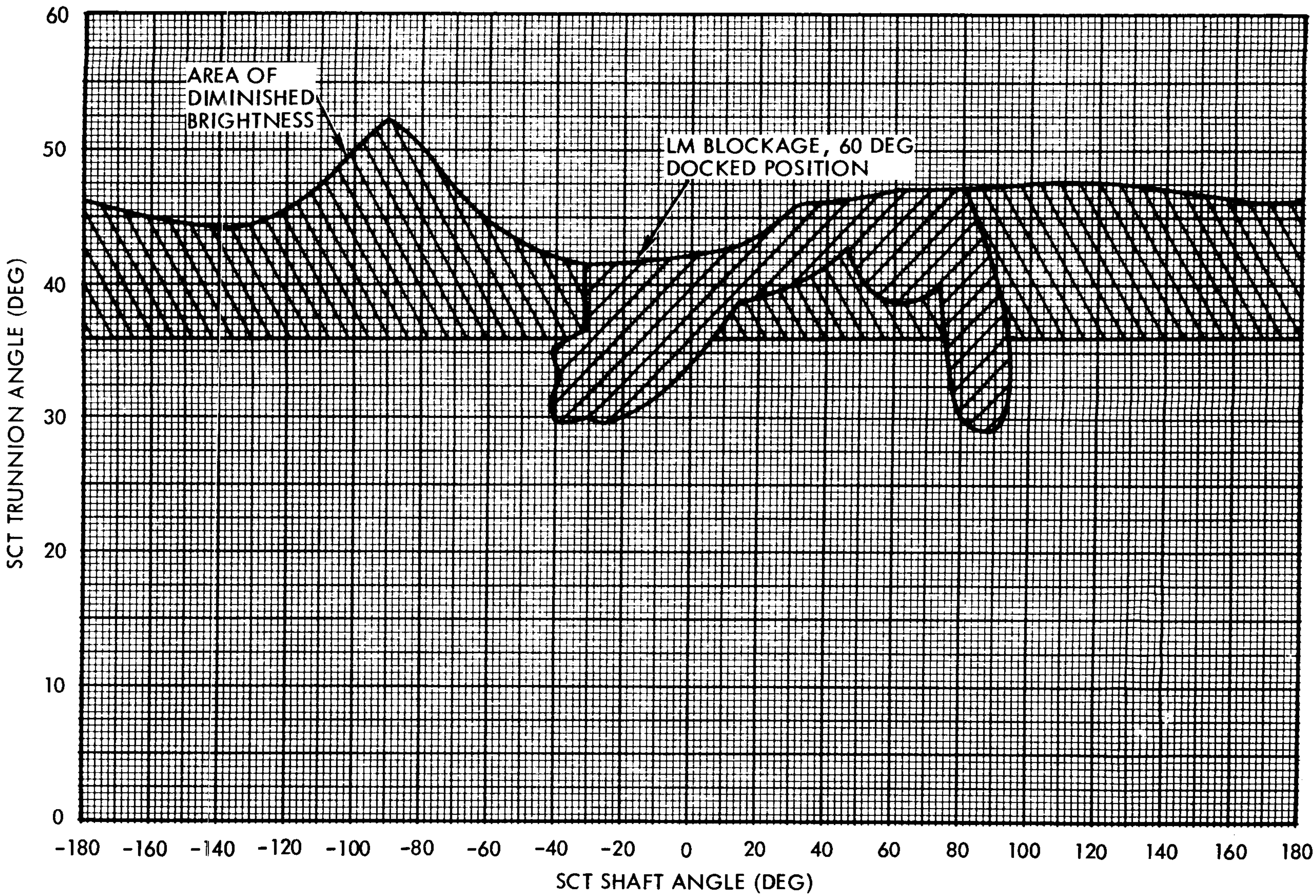


Figure 3. SCT Shaft and Trunnion Limits

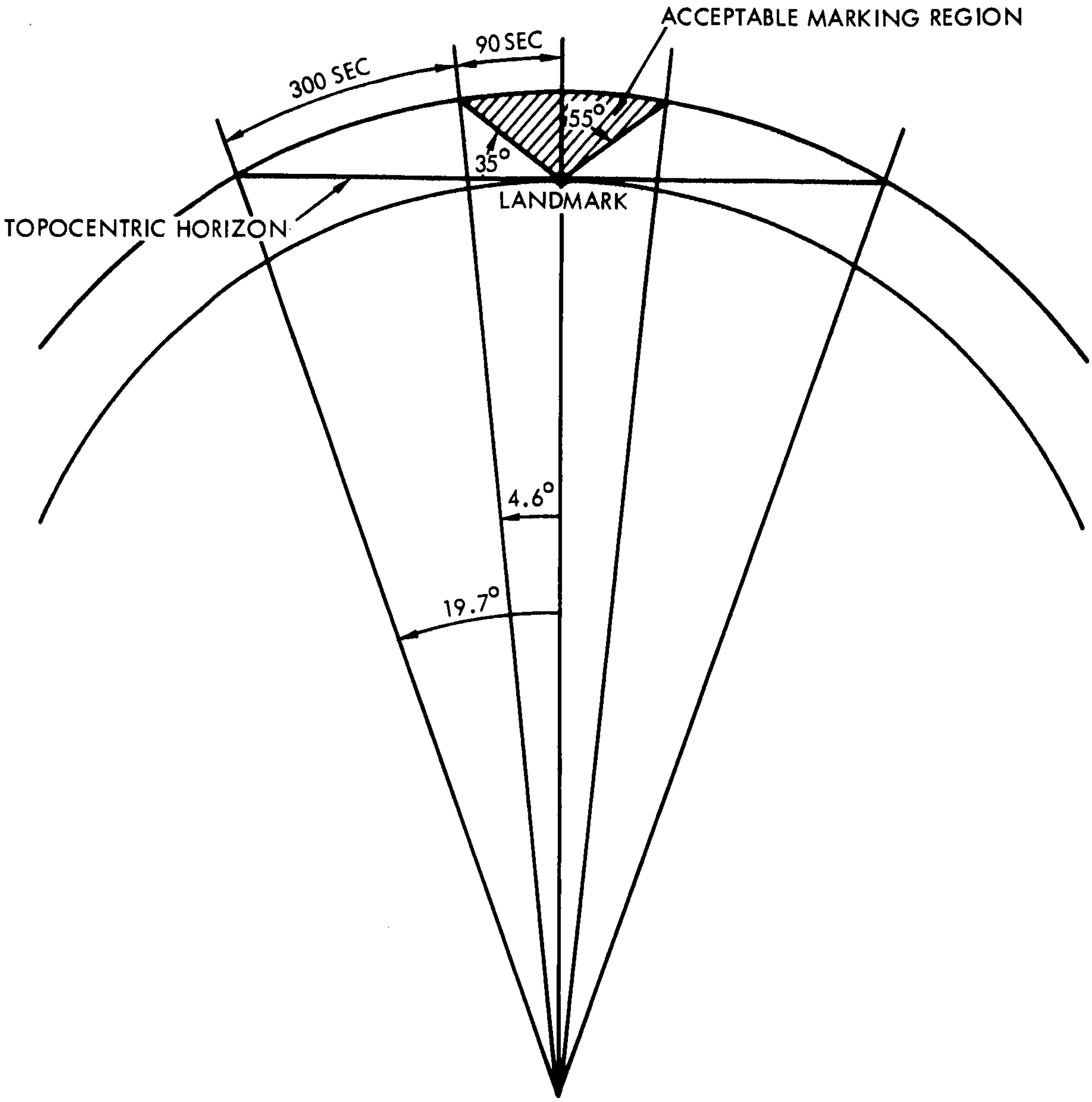


Figure 4. Landmark Tracking Geometry for a 60-Nautical Mile Circular Lunar Orbit

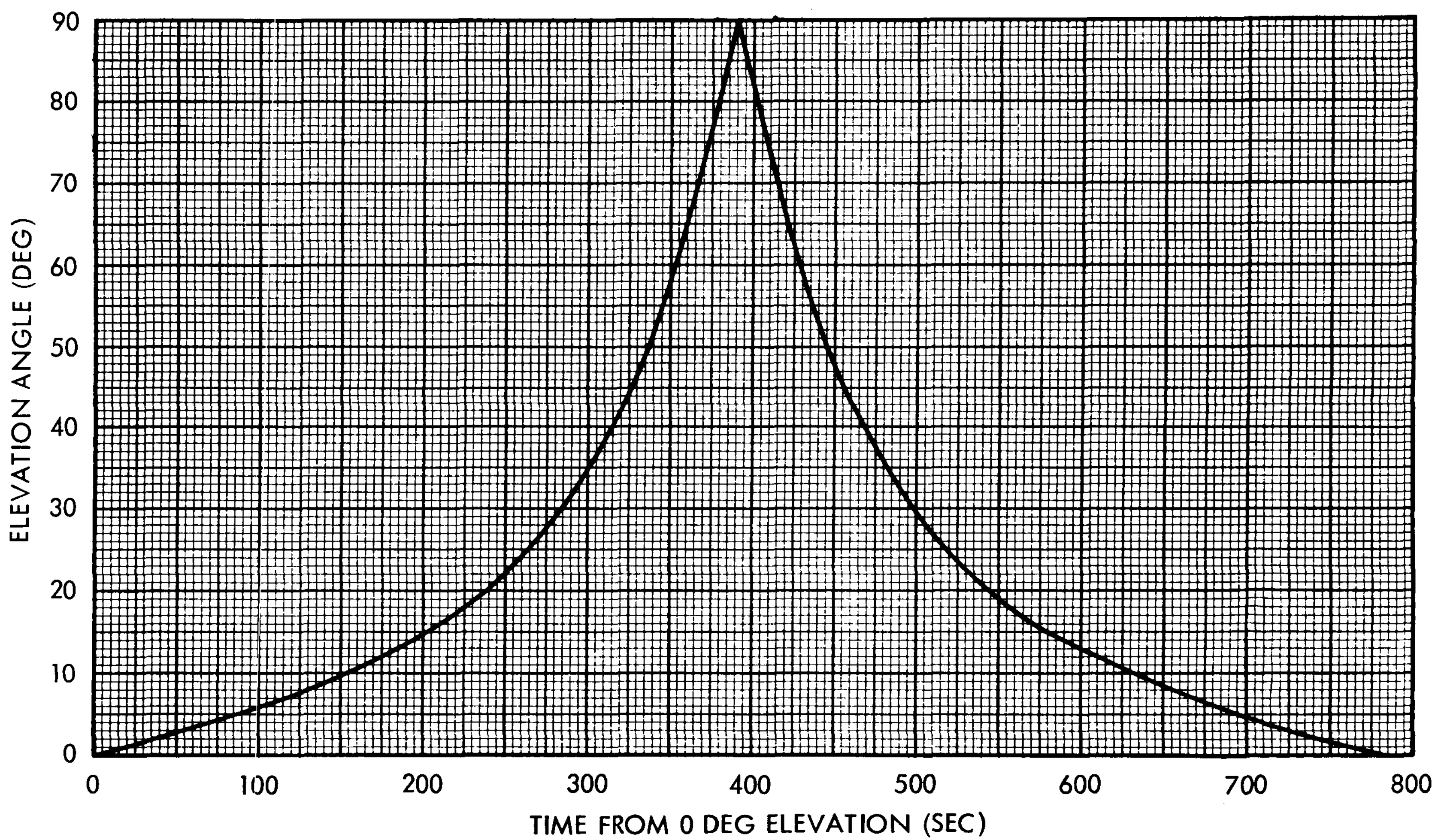


Figure 5. Elevation Angle versus Time Curve for In-plane Landmark

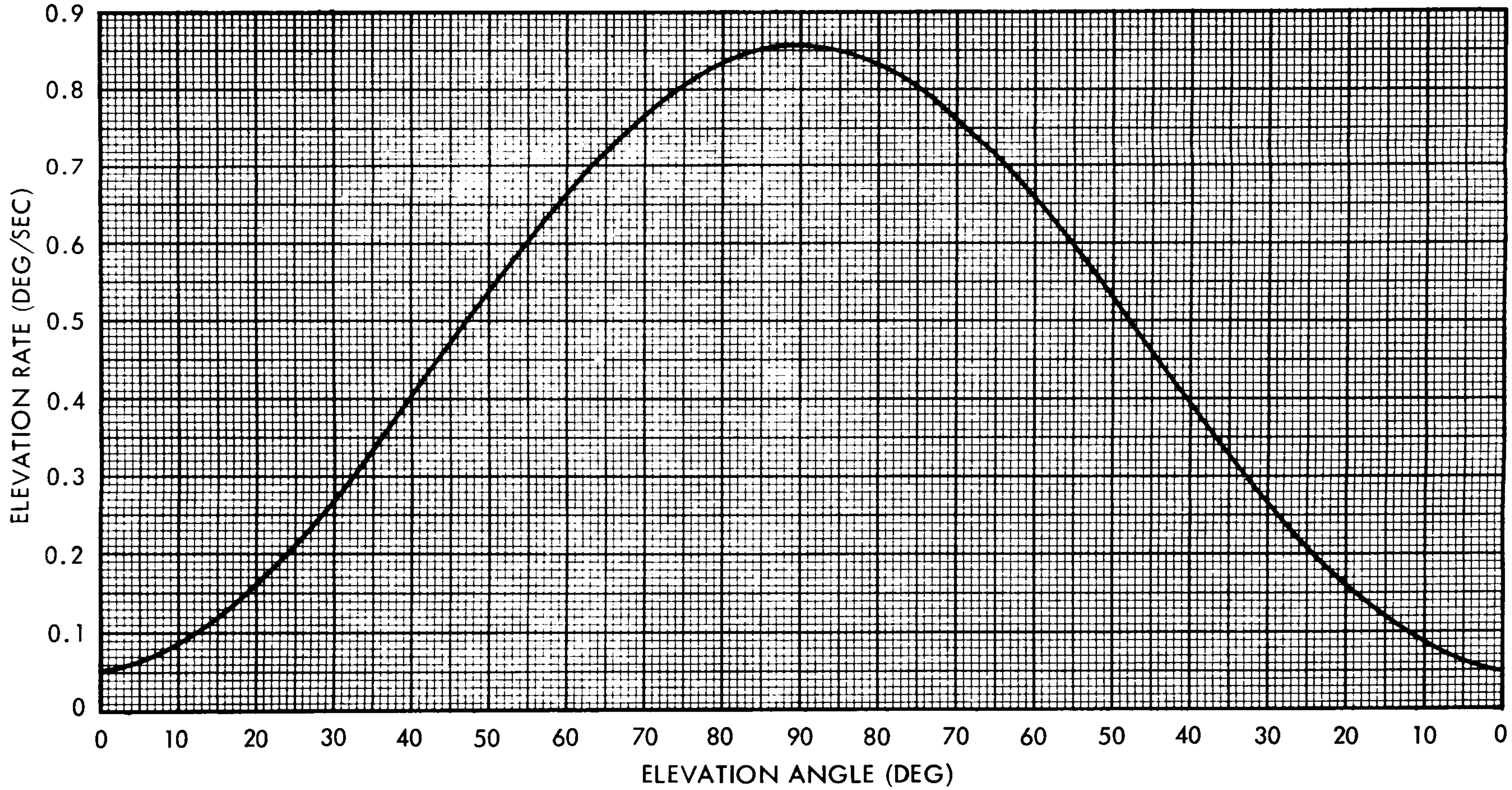


Figure 6. Elevation Rate versus Elevation Angle Curve for In-plane Landmark

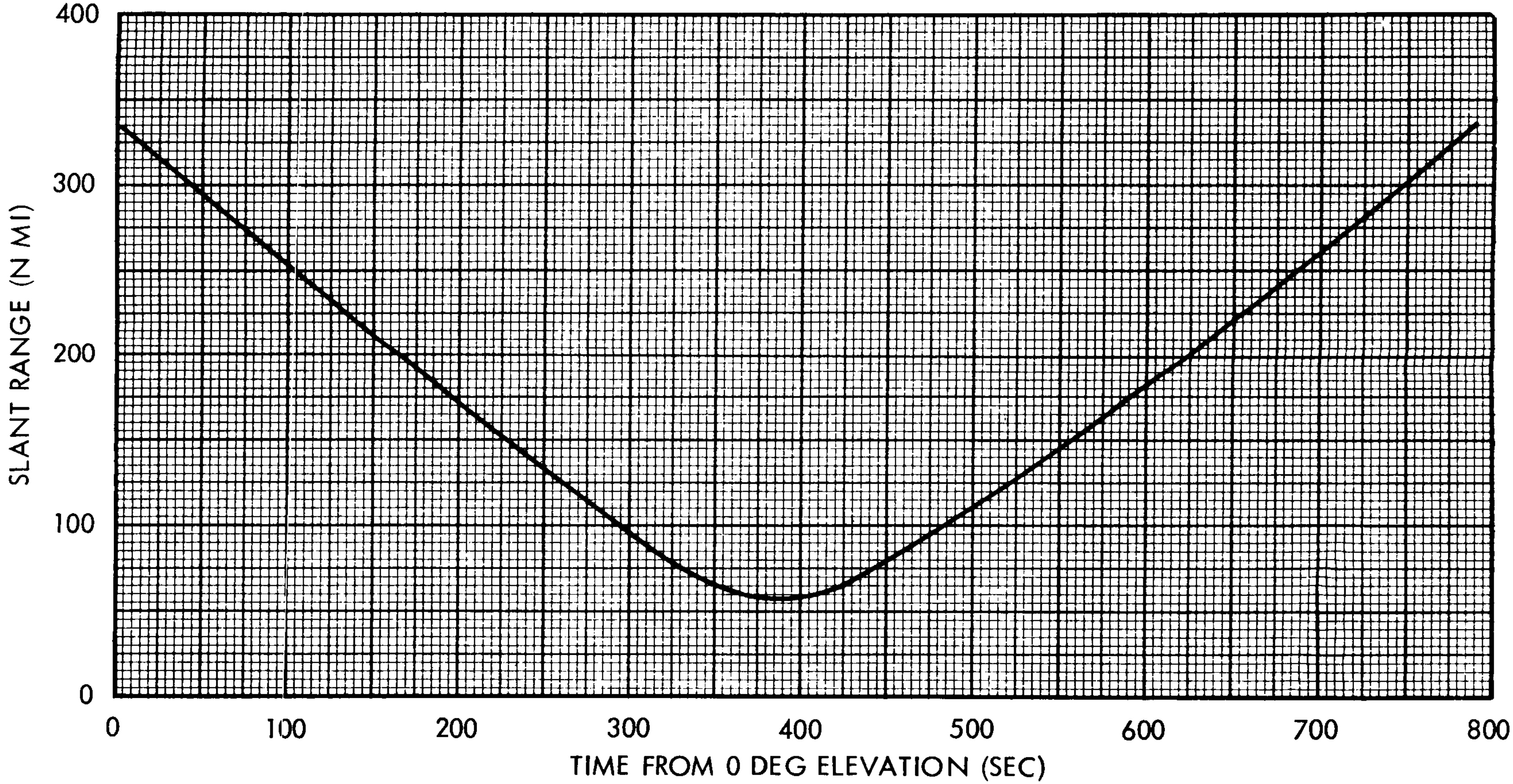


Figure 7. Slant Range versus Time Curve for In-plane Landmark

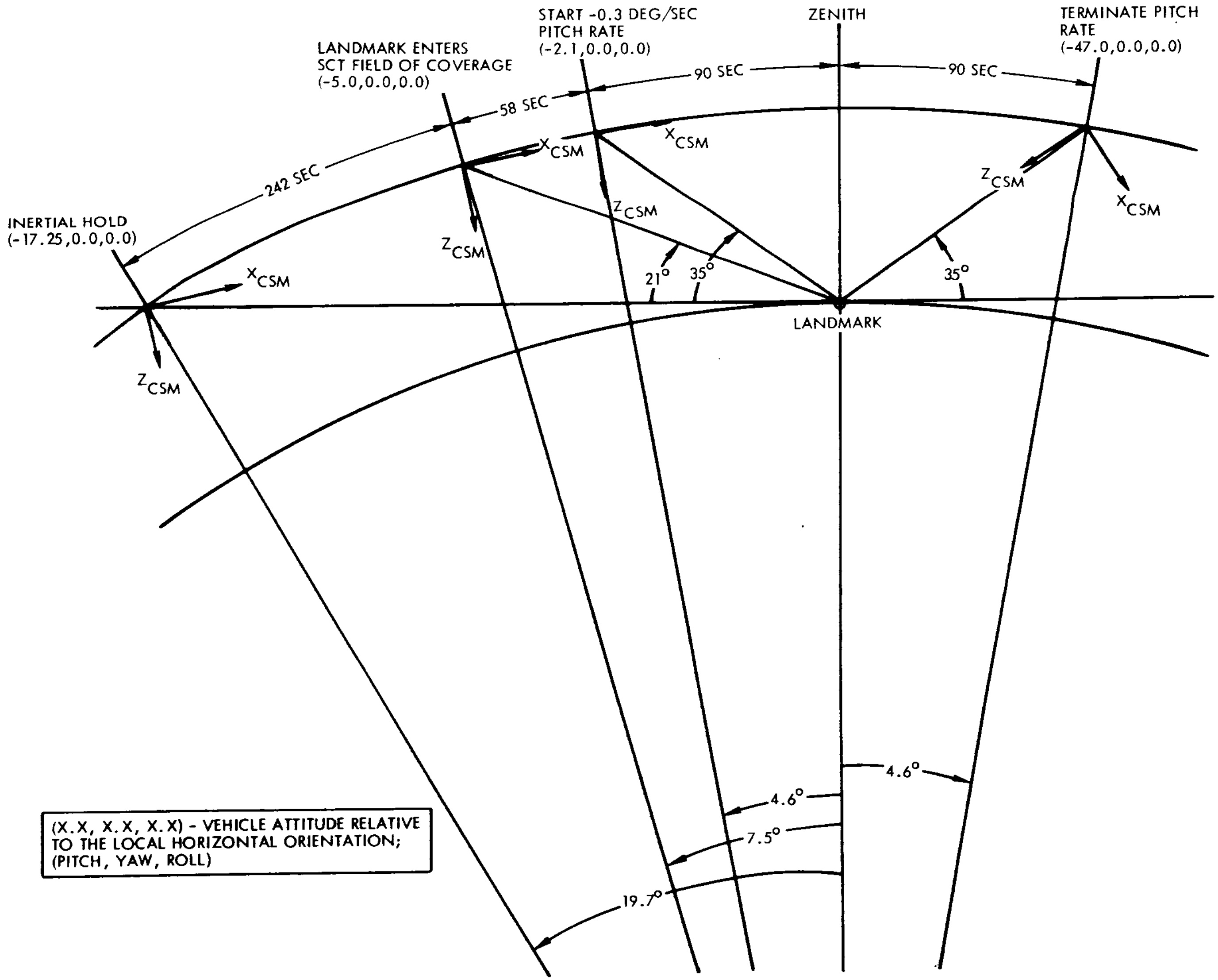


Figure 8. Tracking Geometry for Mode I Landmark Tracking

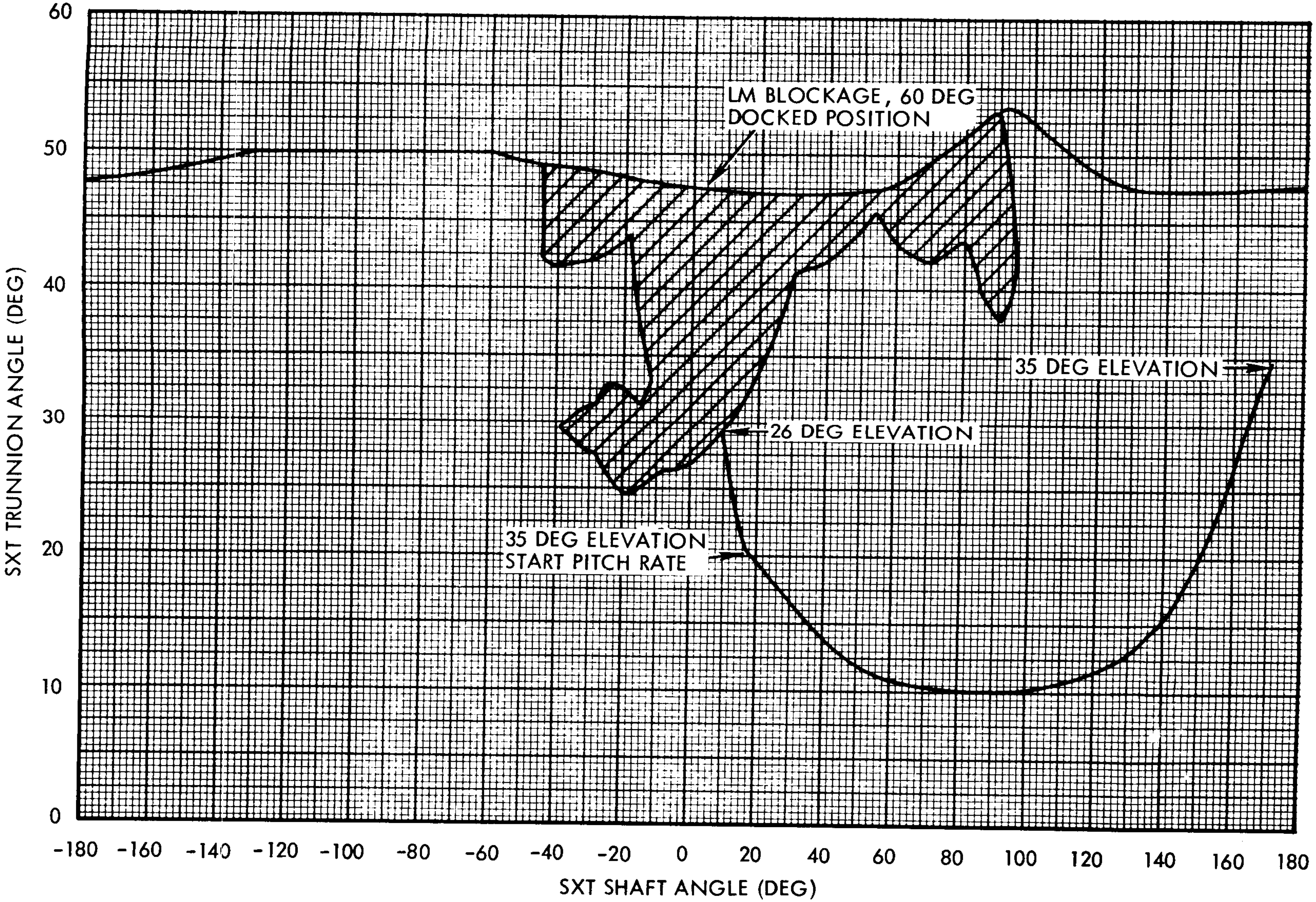


Figure 9. SXT Trunnion Angle versus Shaft Angle Plot for Mode I Landmark Tracking

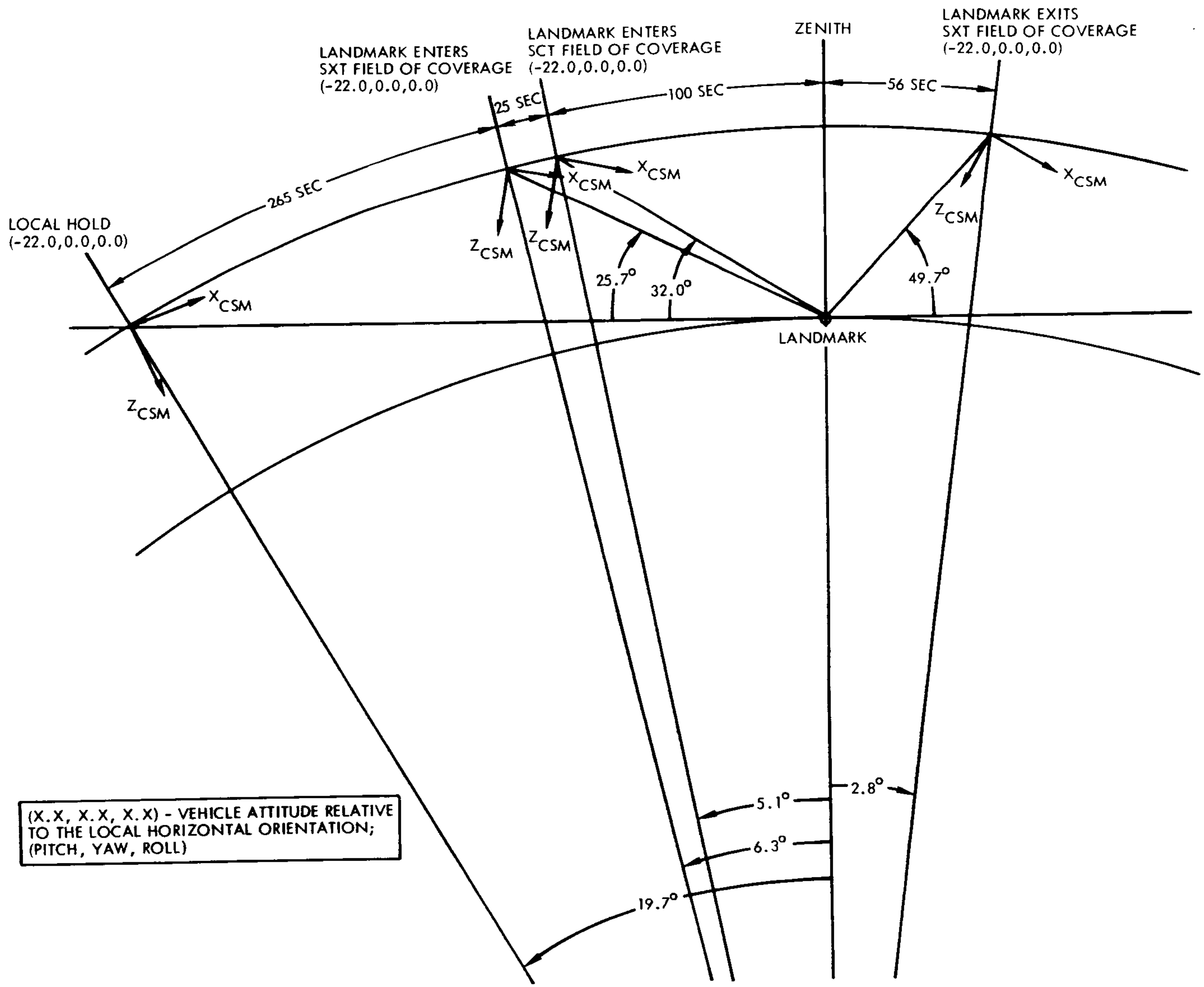


Figure 10. Tracking Geometry for Mode III Undocked Landmark Tracking

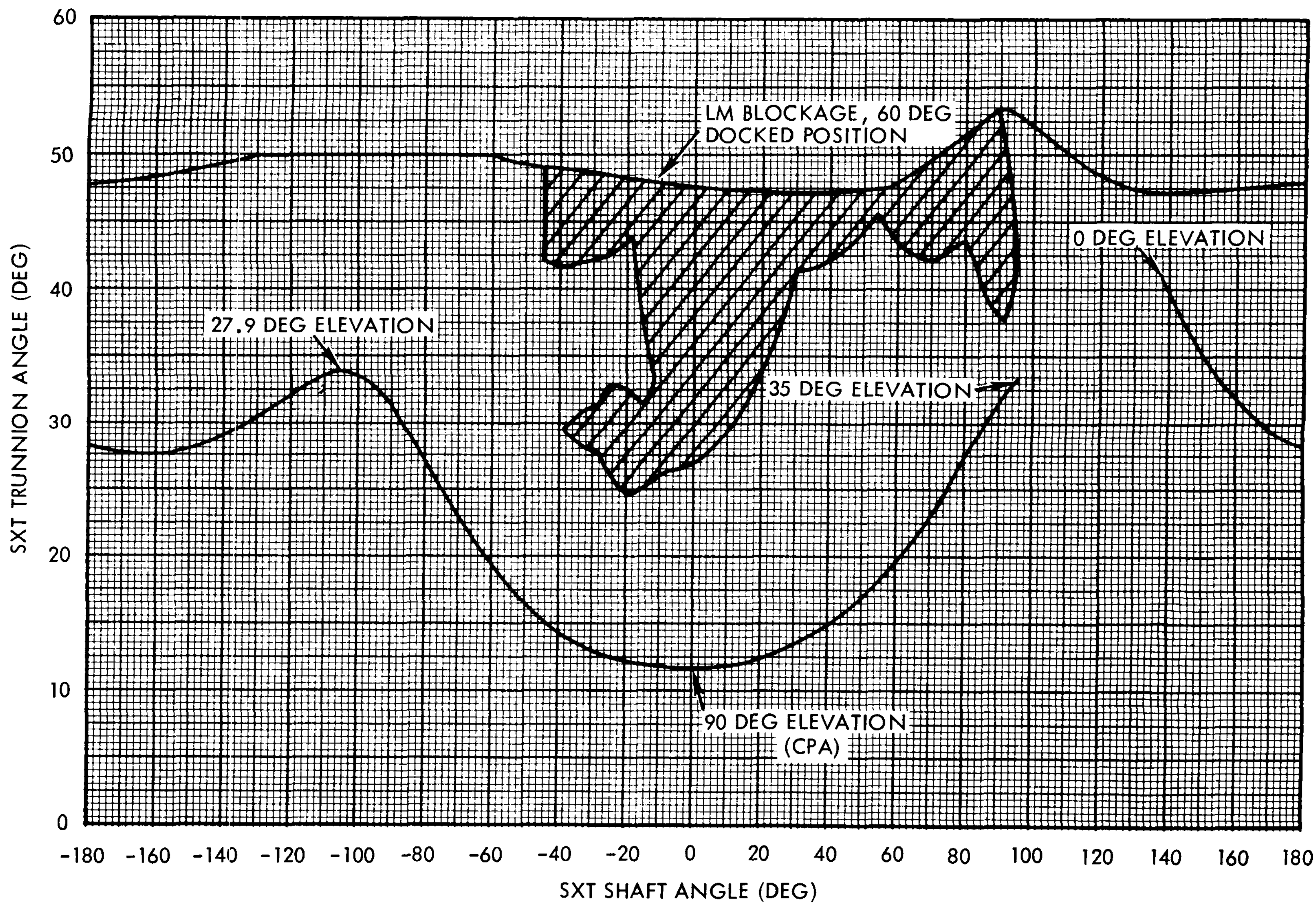


Figure 11. SXT Trunnion Angle versus Shaft Angle Plot for Mode IV Continuous Roll Rate

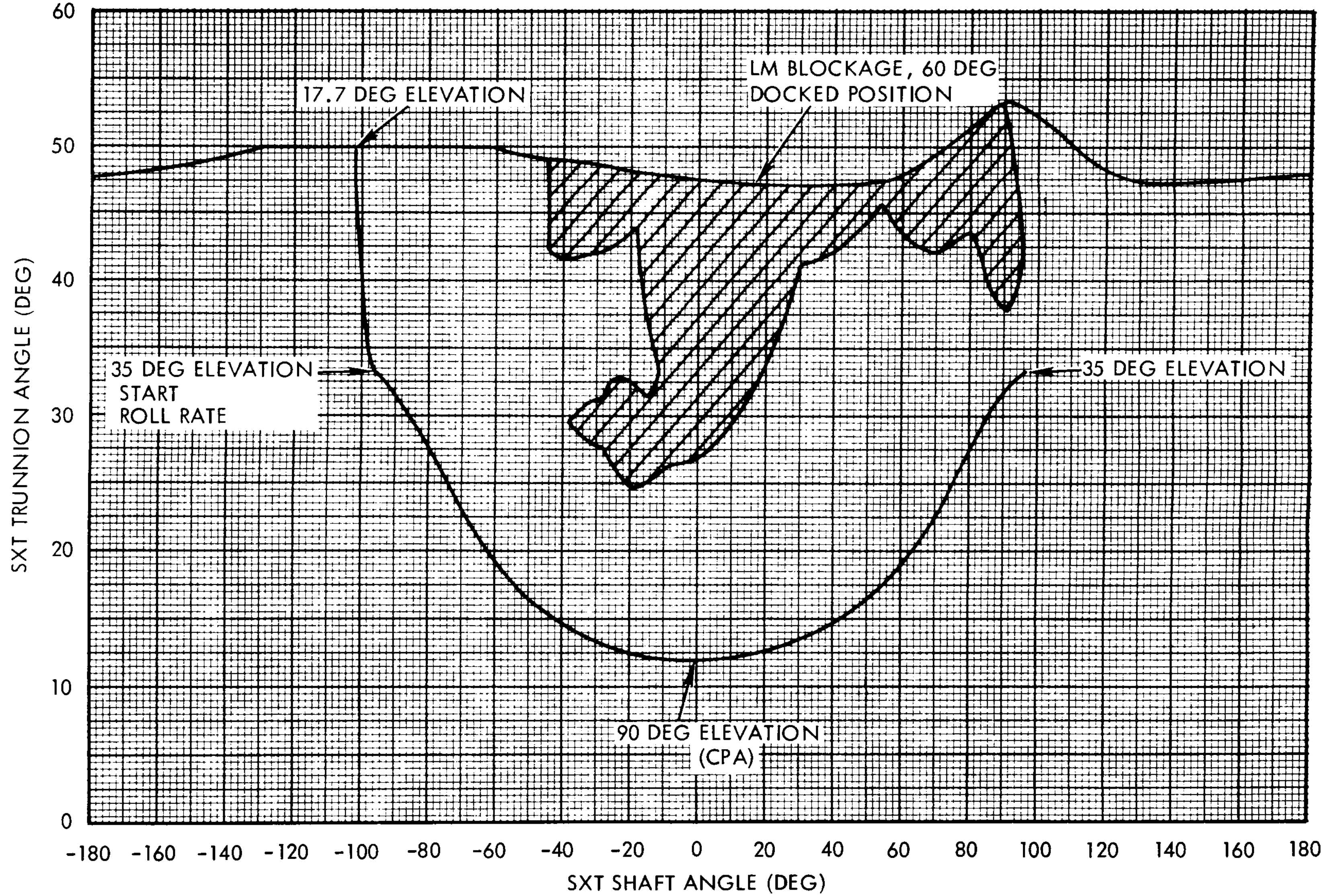


Figure 12. SXT Trunnion Angle versus Shaft Angle Plot for Mode IV Landmark Tracking

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1. CSM/LM Spacecraft Operational Data Book, Volume 1, Revision 1. NASA MSC SNA-8-D-007 (I) Rev. 1, November 1, 1968.

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3. Mission Requirements SA-505/CSM-106/LM-4 F Type Mission. NASA MSC SPD9-R-037, February 11, 1969.

4. Preliminary Lunar Orbit Attitude Sequence for Mission F. MSC IN 69-FM-51, February 21, 1969.

CHANGE HISTORY FOR 69-FM-81

| Change no. | Date | Description |
|---|---|---|
| 1 | 7/31/69 | Replacement figures of CSM/LM configuration reflect new data. |

CHANGE SHEET

FOR

MSC INTERNAL NOTE 69-FM-81 DATED APRIL 11, 1969

LUNAR LANDMARK TRACKING ATTITUDE STUDIES

By C. R. Hunt

Mission Design Section

TRW Systems Group

Change 1 by James T. Blucker

July 31, 1969

Ronald L. Berry

Ronald L. Berry, Chief
Lunar Mission Analysis Branch

John P. Mayer, Chief
Mission Planning and Analysis Division



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1. Replace pages 17, 18, and 19.

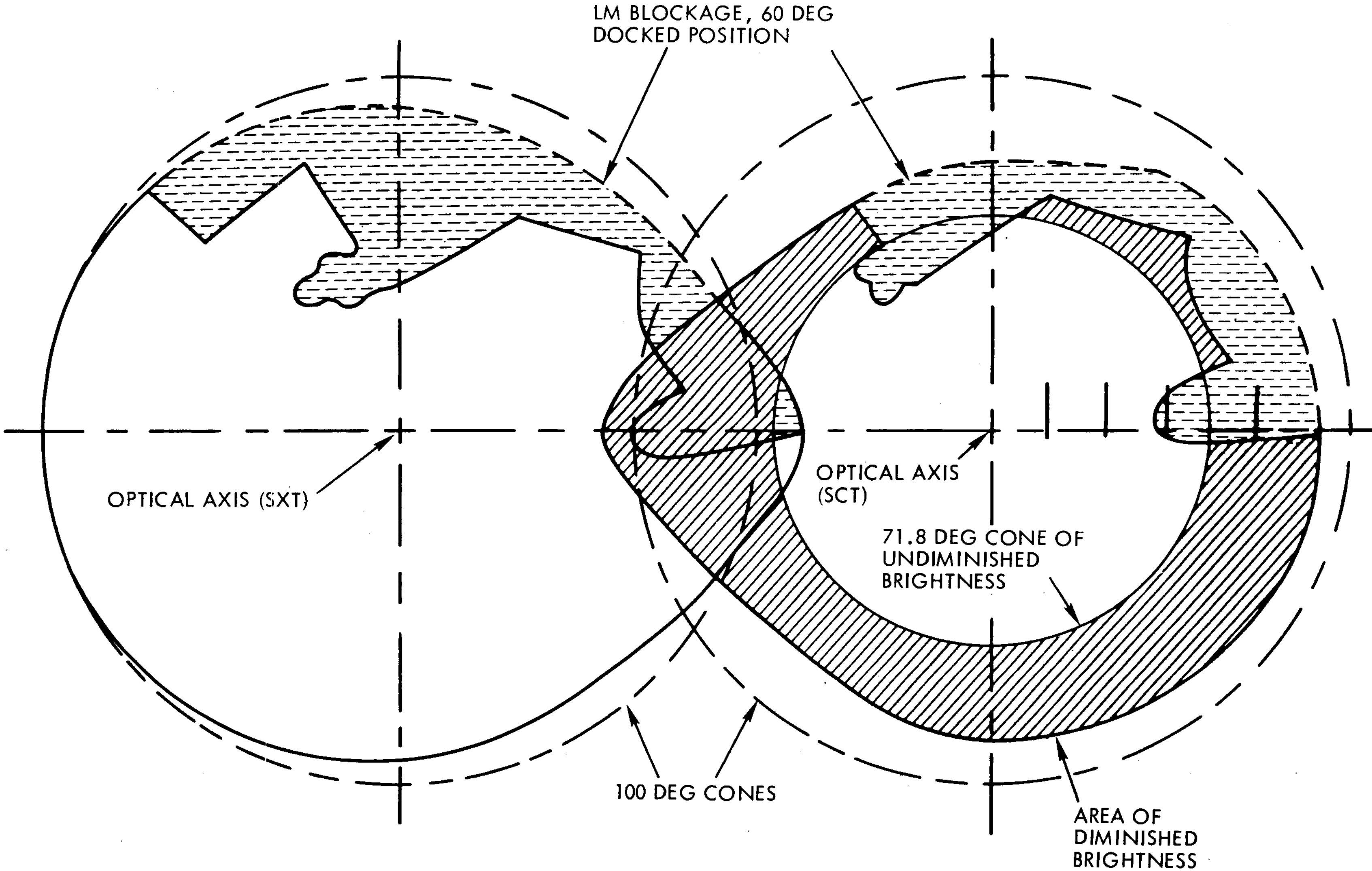


Figure 1. SXT and SCT Fields of Coverage

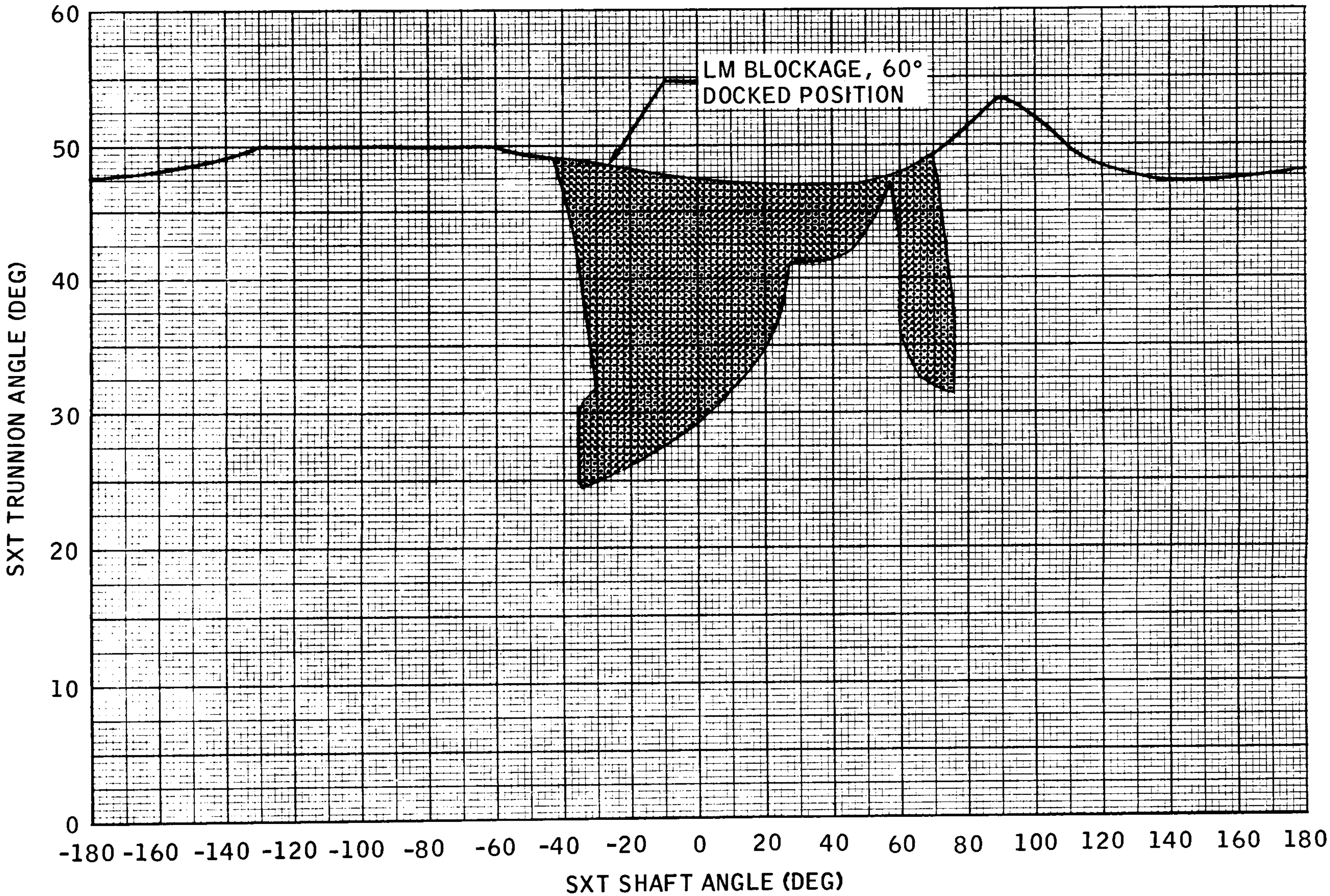


Figure 2. Revised SXT Shaft and Trunnion Limits

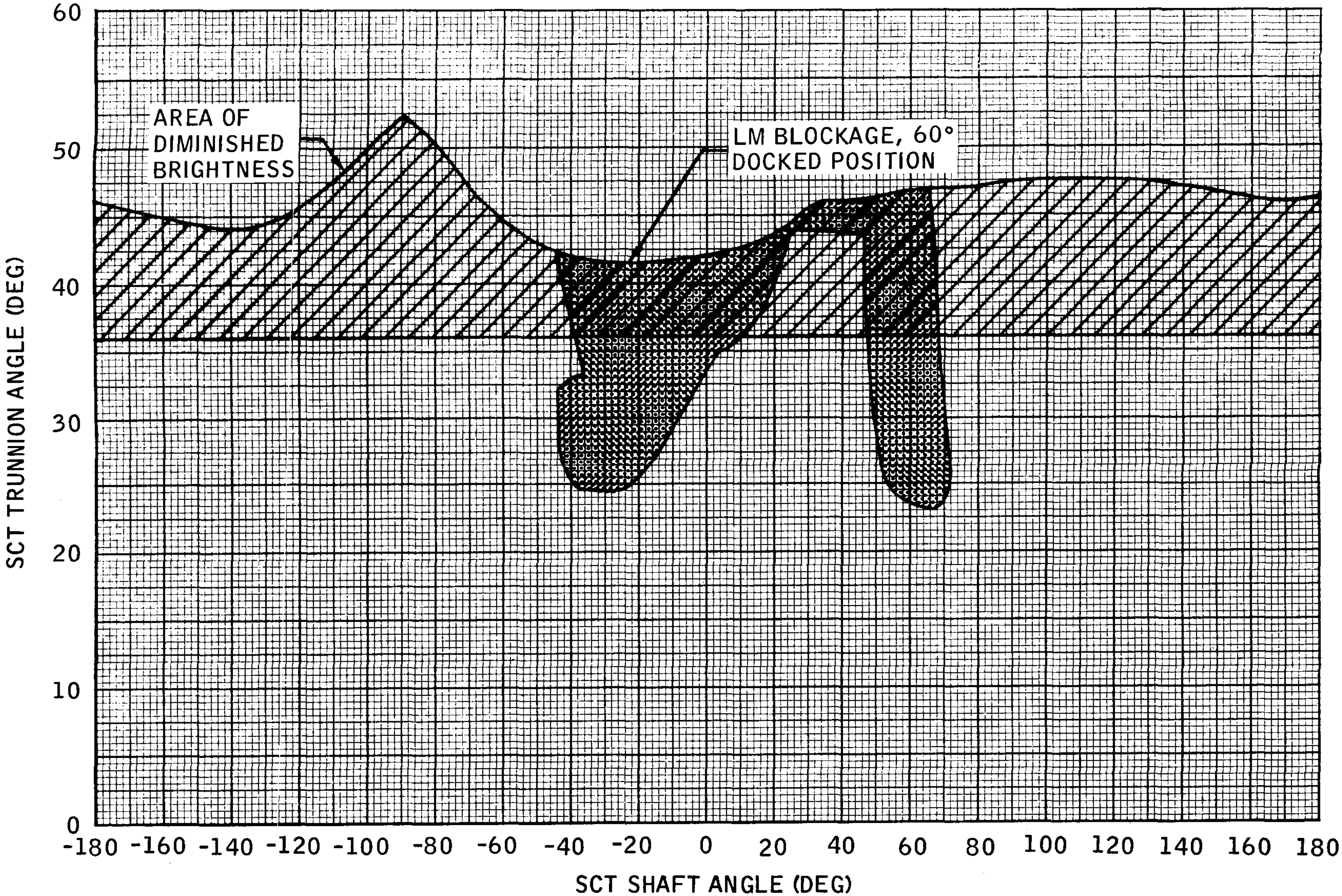


Figure 3. Revised SCT Shaft and Trunnion Limits

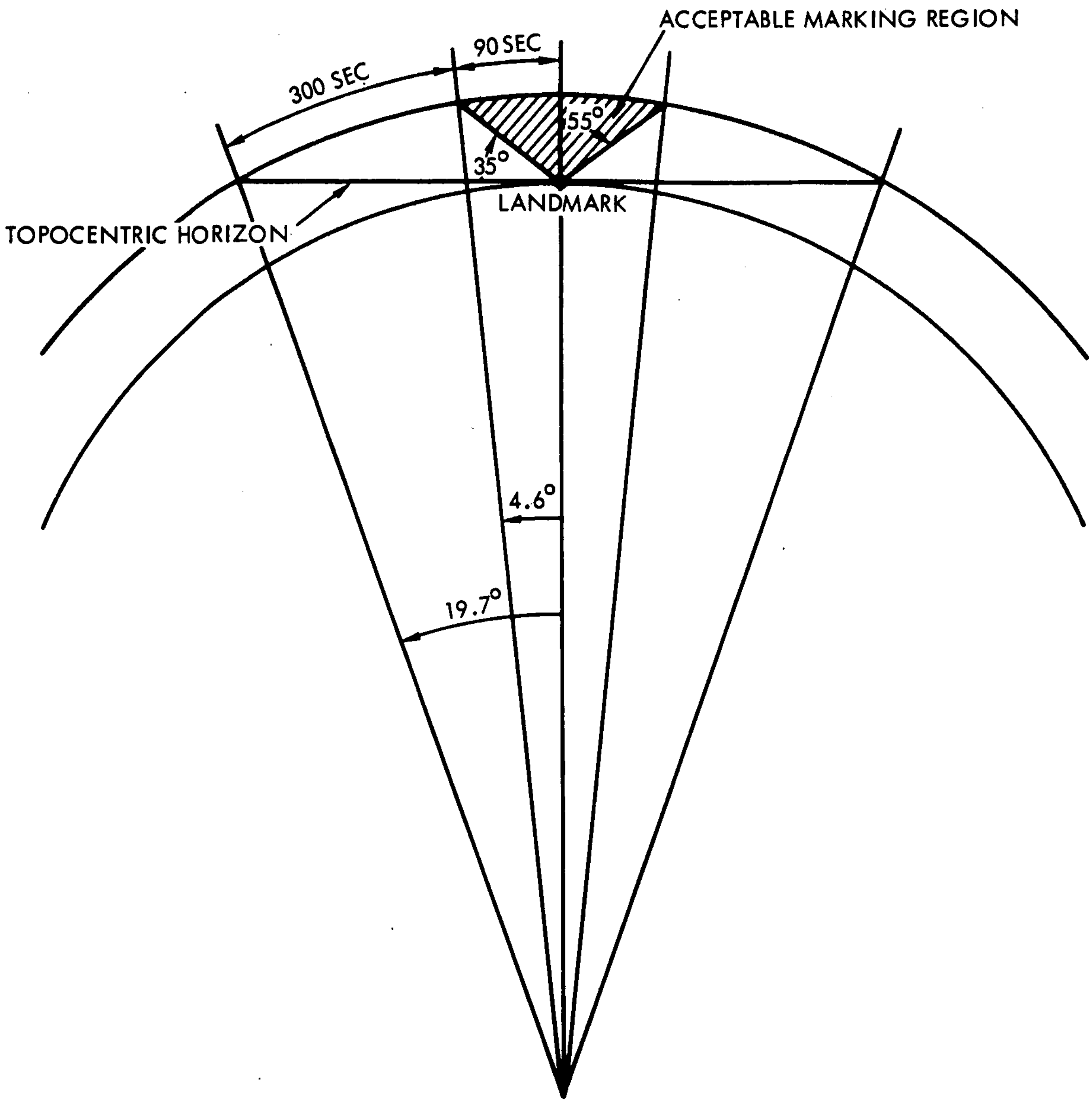


Figure 4. Landmark Tracking Geometry for a 60-Nautical Mile Circular Lunar Orbit

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

# *Memorandum*

NASA-Manned Spacecraft Center
Mission Planning & Analysis Division

TO : See List Below

DATE: JUL 2 9 1969
69-FM47-250

FROM : FM/Mission Planning and Analysis Division

SUBJECT: Change Sheet for MSC Internal Note No. 69-FM-81

1. Reference: MSC Internal Note No. 69-FM-81, "Lunar Landmark Tracking Attitude Studies," C. R. Hunt, TRW Systems, April 11, 1969.

2. The Apollo command module sextant and scanning telescope coverage with the LM attached defined in figures 2 and 3, respectively, have been slightly modified. Figures 1 and 4 of the attached illustrates how the revised coverages have been changed from those defined in the reference. Figures 2 and 3 of the attached illustrate the revised coverages as they should appear in the reference, and these should replace the present figures 2 and 3 of this internal note.

3. The revised coverages will not alter the tracking attitude of any of the three modes described in the reference.

James C. McPherson, Chief
Mathematical Physics Branch

APPROVED BY:

John P. Mayer
Chief, Mission Planning
and Analysis Division

Attachment

Distribution: (See attached list)

FM4:TJBlucker:rmr

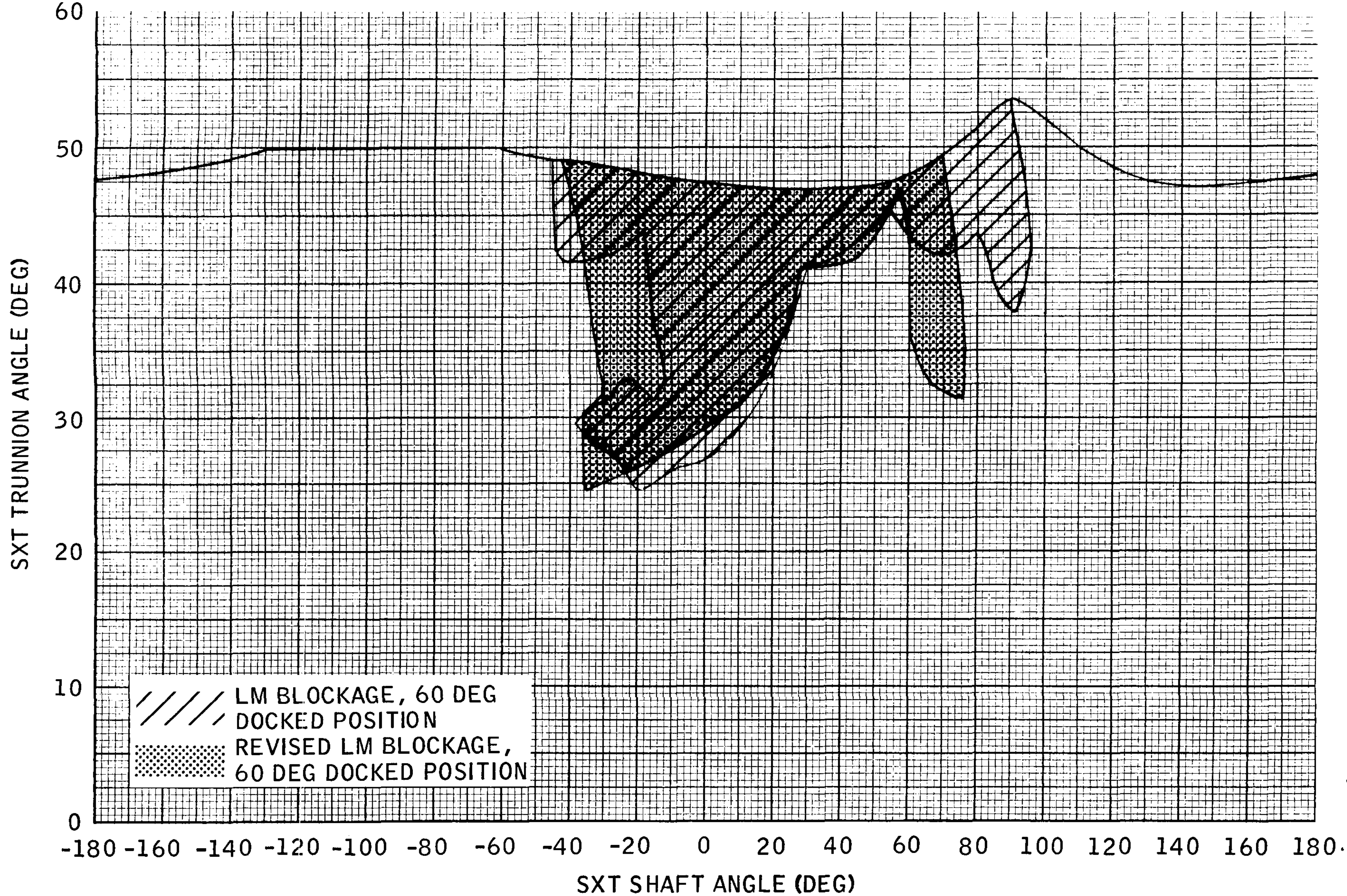


Figure 1. SXT Shaft and Trunnion Limits

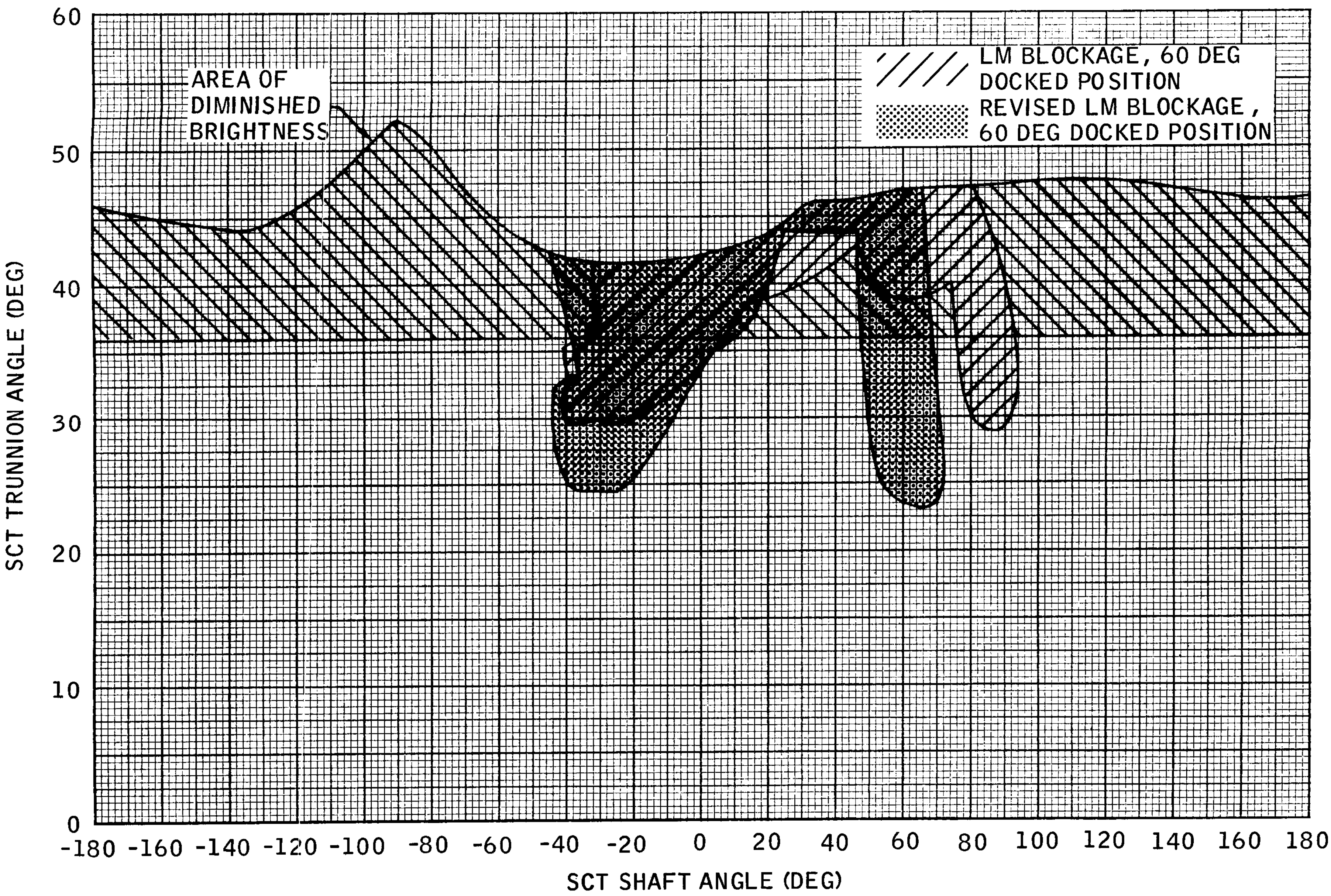


Figure 4. SCT Shaft and Trunnion Limits